Techniques for Iterative Design of Observer Field Tests

John G. Bennett
U.S. Army Tank-automotive and Armaments Command
Warren, MI 48317-9000

ABSTRACT

In field tests to compare the observability of combat vehicles, the test designer must select the optimum number of observation opportunities in order to balance collecting enough data to draw valid conclusions against the high cost of supporting vehicles and personnel at a test site. The test designer, however, generally lacks key parameters for the efficient design of the test. Namely, the designer lacks the detection probabilities of the vehicles at each range. The standard deviation of the difference in detection probability depends upon the detection probability itself. Therefore, the test designer must select the number of observations for each range based upon the conservative assumption that the probabilities are near 50%, the probability for the maximum standard deviation. In this paper, an iterative technique of test design is explored in order to improve the efficiency of observability tests.

THE EXPERIMENTAL SITUATION

Figure 1 illustrates a typical test setup for a test of observability. Observers are stationed at a fixed site and attempt to detect a vehicle in their field of view. For each observation opportunity, the test personnel record the number of detections. In analyzing the data, the analyst groups the observations into range bins and compares the proportion of detections for each test vehicle.

For such a field test, the test designer must select the optimum number of observation opportunities at each range. The designer must balance collecting enough data to draw valid conclusions against the high cost of supporting vehicles and personnel at a test site.

DESIGNING THE EXPERIMENT

The test designer selects the number of observations in order to achieve two objectives. First, the number of observations must be large enough so that the probabilities of errors are below the desired level. And, second, the number of observations must be as small as possible to minimize testing time and cost.

Table I illustrates the types of errors that can occur in drawing conclusions from an observation test. The goal of an observation test is to judge whether the observed difference in detection probability, P_d, is unusual enough to reject the null hypothesis that Vehicle A and Vehicle B have the same P_d. If the analyst concludes that the null hypothesis cannot be rejected, then either the analyst has made a correct decision or a Type II error. On the other hand, a decision to reject the null hypothesis will be either correct or a Type I error. In terms of

1

Report Documentation Page	Form Approved OMB No. 0704-0188

1. REPORT DATE **01 APR 2002**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Techniques for Iterative Design of Observer Field Tests**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Bennett, John G.**	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **USA TACOM 6501 E 11 Mile Road Warren, MI 48397-5000**	8. PERFORMING ORGANIZATION REPORT NUMBER **16146**

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**7**	

countermeasure effectiveness, a Type I error is an erroneous conclusion than an ineffective countermeasure is effective, while a Type II error miss judges an effective countermeasure.

In a previous paper [1], I discussed the number of observation opportunities required to control the probability of these errors. For the case of an average P_d of 0.5, Figure 2 plots the number of observations required to maintain the probability of Type I and Type II errors at less than 5%. For example, 85 observations of each vehicle are adequate for an observed 0.15 difference to be significant with less than 5% chance of a Type I error. On the other hand, for less that 5% chance of committing a Type II error when the underlying probabilities differ by 0.15, the requirement is 316 observation opportunities per vehicle.

AN ITERATIVE TECHNIQUE FOR TEST DESIGN

An iterative technique can reduce the number of observation opportunities required for a test. Observation data is described by the binary distribution. But the binary distribution has the property that the standard deviation depends upon the probability. If p is the probability and N is the number of trials, then the standard deviation of the number of successes, σ, is given by

$$\sigma = \sqrt{Np(1-p)} \qquad (1)$$

And the standard deviation of the proportion of successes is given by

$$\frac{\sigma}{N} = \sqrt{\frac{p(1-p)}{N}} \qquad (2)$$

Figure 3 plots Equation 2 for an N of 100, 200 and 300. Figure 4 plots the same equation normalized to its maximum at p = 0.5.

Figure 5 further shows how the number of trials change with probability if the standard deviation is held fixed. For example, in comparison to a probability of 0.5, only 60% as many trials are need at a probability of 0.1.

To use this property of the binary distribution, the test designer modifies the test matrix as the test progresses. Early test results yield estimates of the probability of detection for each vehicle at each range. Based on these estimates, the test designer reallocates the number of observations among the ranges, improving the efficiency of the test design. Figure 5 illustrates a sample of the improvement in efficiency that this technique can achieve. Initially the test designer would have selected the number of observations at each test range by assuming the worst-case value of $P_d = 0.5$. But as the test progresses, the designer would use estimates of P_d from the early measures to redesign the test. For example, at range 20, the designer would reduce the number of observations from 314 to 251. Overall in this sample test, the test designer would reduce the number of observations from 1570 to 1193, a reduction of 24%.

Z

CONCLUSION

In this paper, I have presented an iterative technique of using early test results in an observation test to improve the overall efficiency of the test design.

REFERENCE

[1] Bennett, John G., Proceedings *of the 2001 Ground Target Modeling & Validation Conference*, Houghton, MI, August 2001.

Possible Outcomes of Hypothesis Testing

Decision:	Is Vehicle A Less Detectable Than Vehicle B?	
	No	Yes
Accept Null Hypothesis	Correct	Type II Error
Accept Alternative Hypothesis	Type I Error	Correct

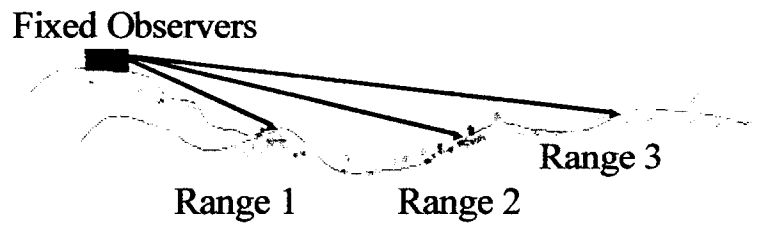Table 1. Definitions of Type I and Type II errors.

3

Test with Fixed Observers

Fixed Observers

Range 1   Range 2   Range 3

Figure 1. Experimental setup for an observer test.

Number of Opportunities
Required to Meet Test Criteria

Pd Difference

Criterion:
Probability of Type II
Error Less Than 5%

Criterion:
Observed Difference
Significant at 95% Confidence

Number of Observations
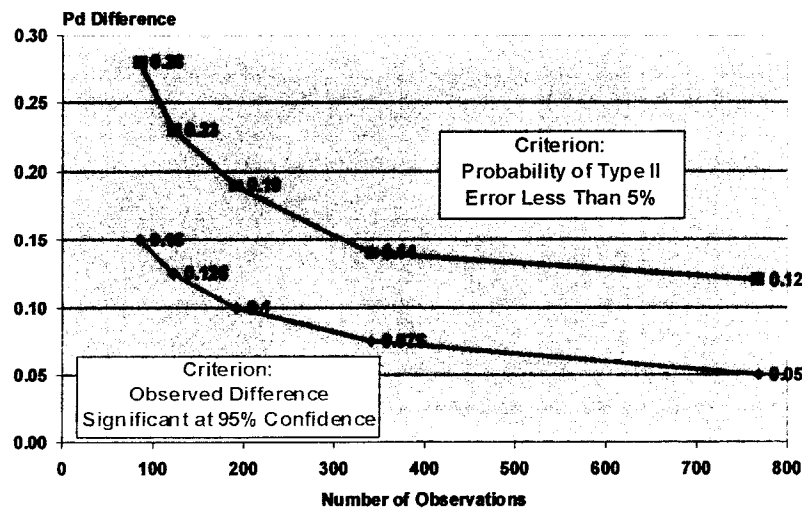
Figure 2. Number of observation opportunities required to meet test criteria.

Initial and Optimum Number of Observations per Vehicle
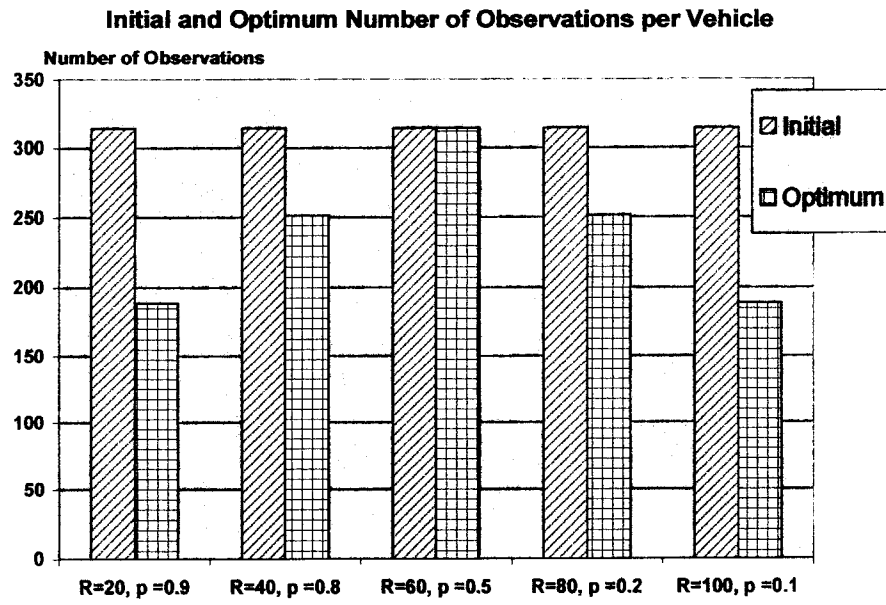
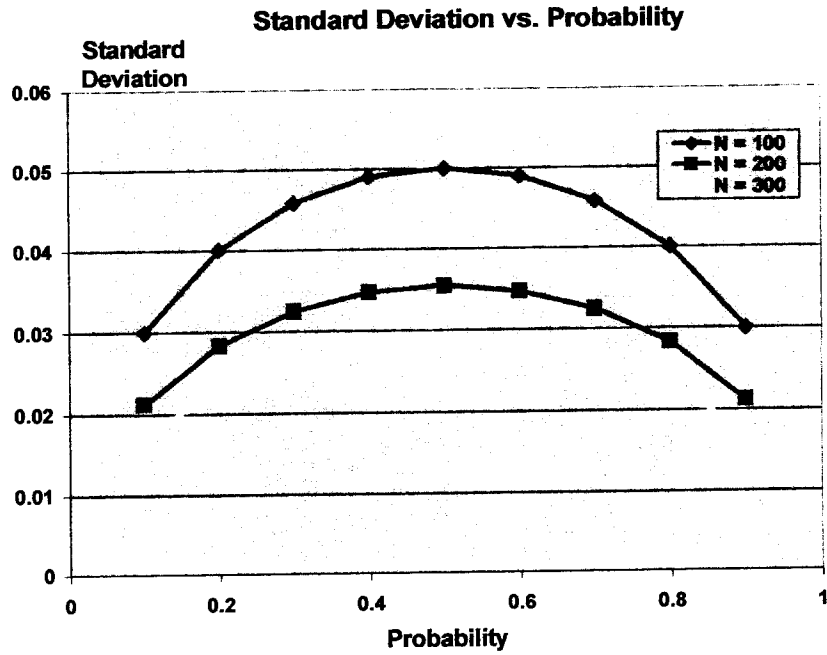Figure 5. An example of iterative design of an observer test.

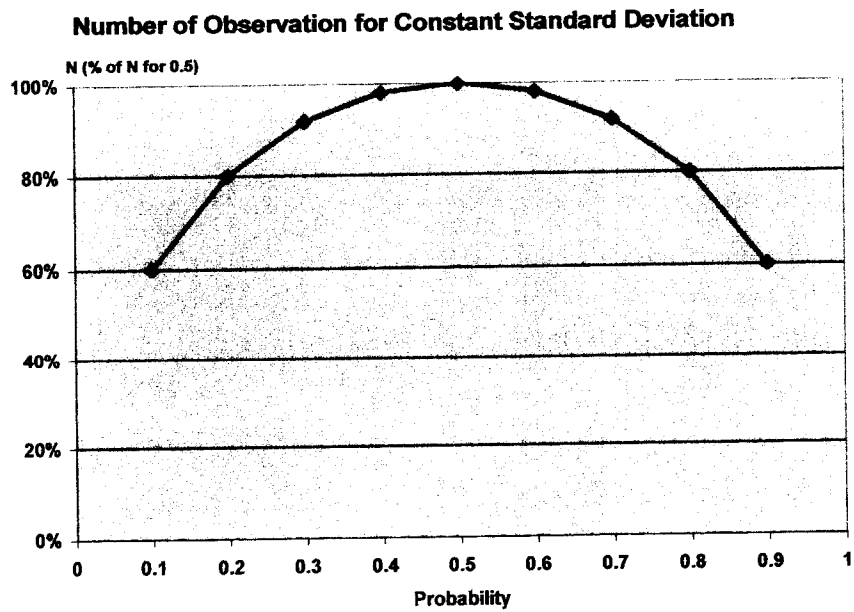Figure 3. Standard deviation of a binary distribution for 100, 200 and 300 trials.

Figure 4. Standard deviation of a binary distribution normalize to probability of 0.5.
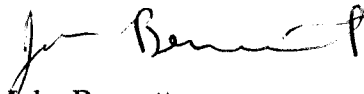
6

21 February 2002

Lisa,

Please submit the attached paper for security and public affairs clearance.

I would like to present the attached paper at the SPIE Aerosense Conference on 1 April 2002 in Orlando, FL. The manuscript is due 4 March.

I believe the paper should be UNCLASSIFIED. The paper discloses nothing about Army systems. Only analysis techniques are discussed.

John Bennett

7